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(54) SEMICONDUCTOR STRUCTURE OF A HIGH SIDE DRIVER AND METHOD FOR MANUFACTURING THE SAME

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H01L 21/00 (2006.01)

(52) **U.S. Cl.** **257/299**; 257/328; 257/335; 257/343; 257/532; 257/E21.397; 257/E27.016; 257/E27.048; 257/E29.012; 257/E29.027; 257/E29.256

(58) **Field of Classification Search** 257/299–343, 257/532, E21.397, E27.016, 48, E29.012, 257/27, 256
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,527,180	A *	7/1985	Oto	257/532
5,258,636	A	11/1993	Rumennik et al.	
5,289,025	A *	2/1994	Lee	257/299
5,536,672	A *	7/1996	Miller et al.	438/3
5,736,774	A	4/1998	Fujihira	
5,801,418	A	9/1998	Ranjan	
5,925,905	A *	7/1999	Hanneberg et al.	257/299
6,124,628	A	9/2000	Fujihira et al.	
6,262,469	B1 *	7/2001	Le et al.	257/532
6,323,539	B1	11/2001	Fujihira et al.	
6,707,101	B2 *	3/2004	Ranjan	257/339
7,042,701	B2 *	5/2006	Diorio et al.	361/301.4
7,309,894	B2 *	12/2007	Jeon et al.	257/328
2002/0017683	A1	2/2002	Jeon	

* cited by examiner

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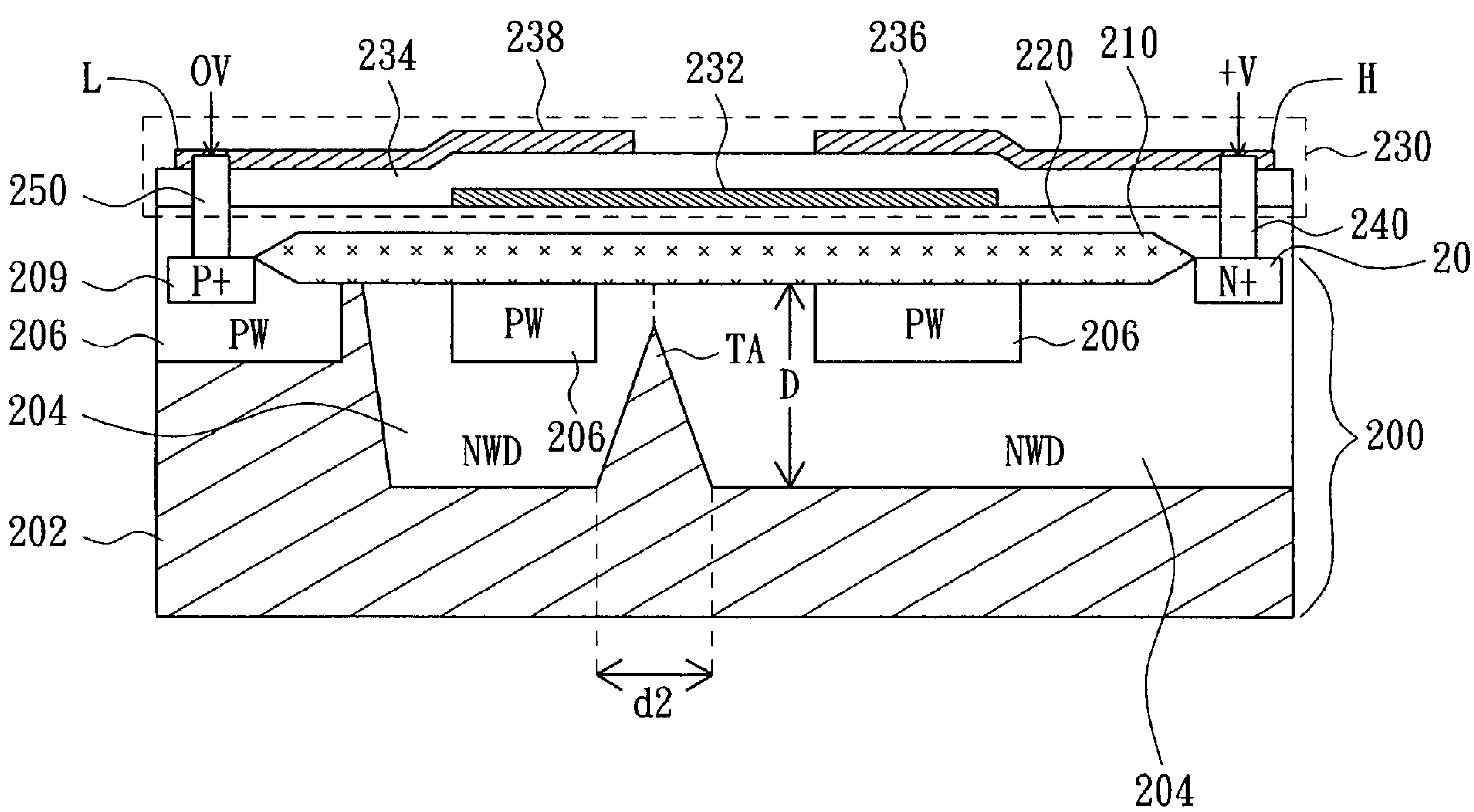
(57) **ABSTRACT**

A semiconductor structure of a high side driver and method for manufacturing the same is disclosed. The semiconductor of a high side driver includes an ion-doped junction and an isolation layer formed on the ion-doped junction. The ion-doped junction has a number of ion-doped deep wells, and the ion-doped deep wells are separated but partially linked with each other.

17 Claims, 5 Drawing Sheets



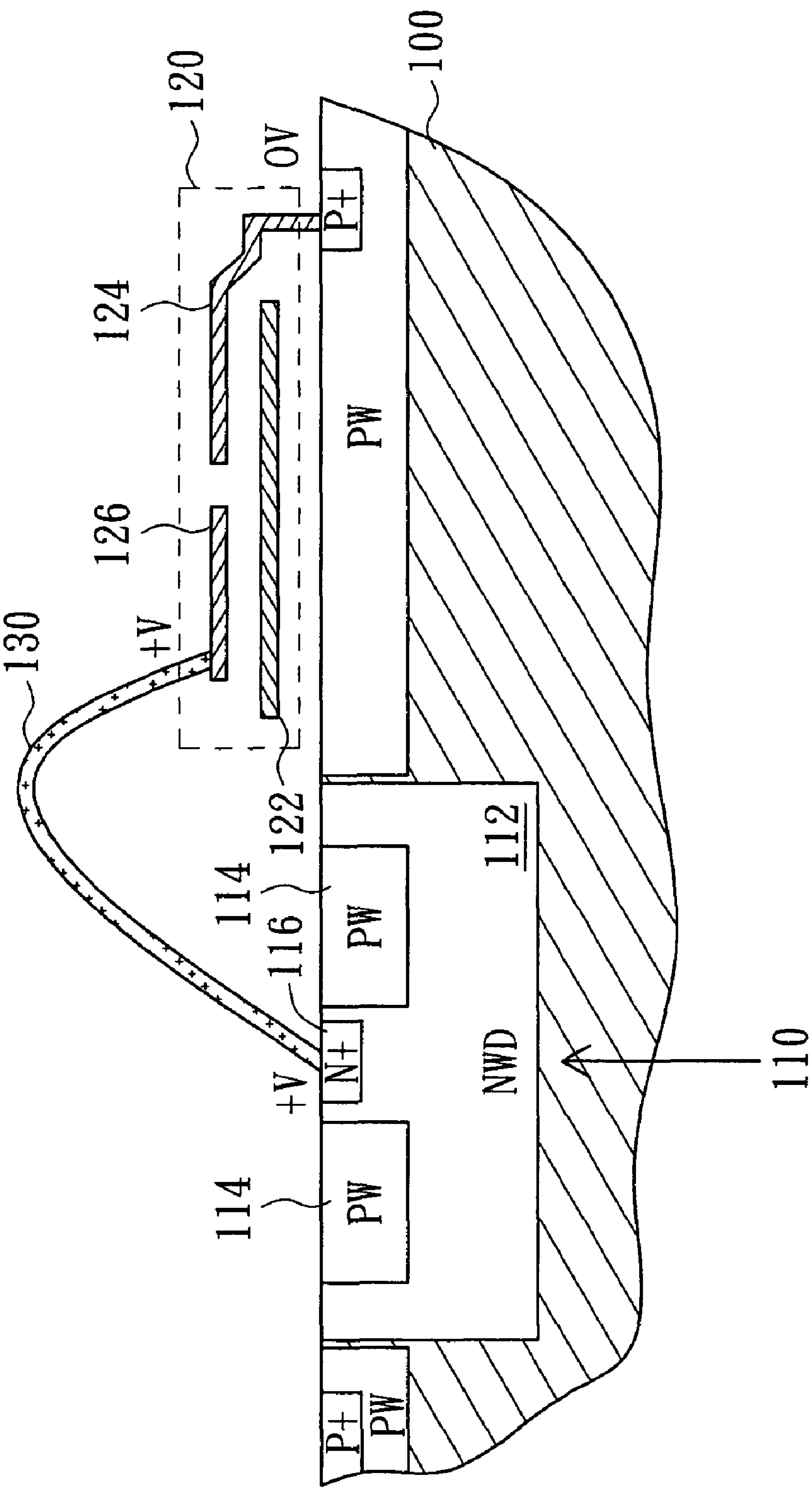


FIG. 1(PRIOR ART)

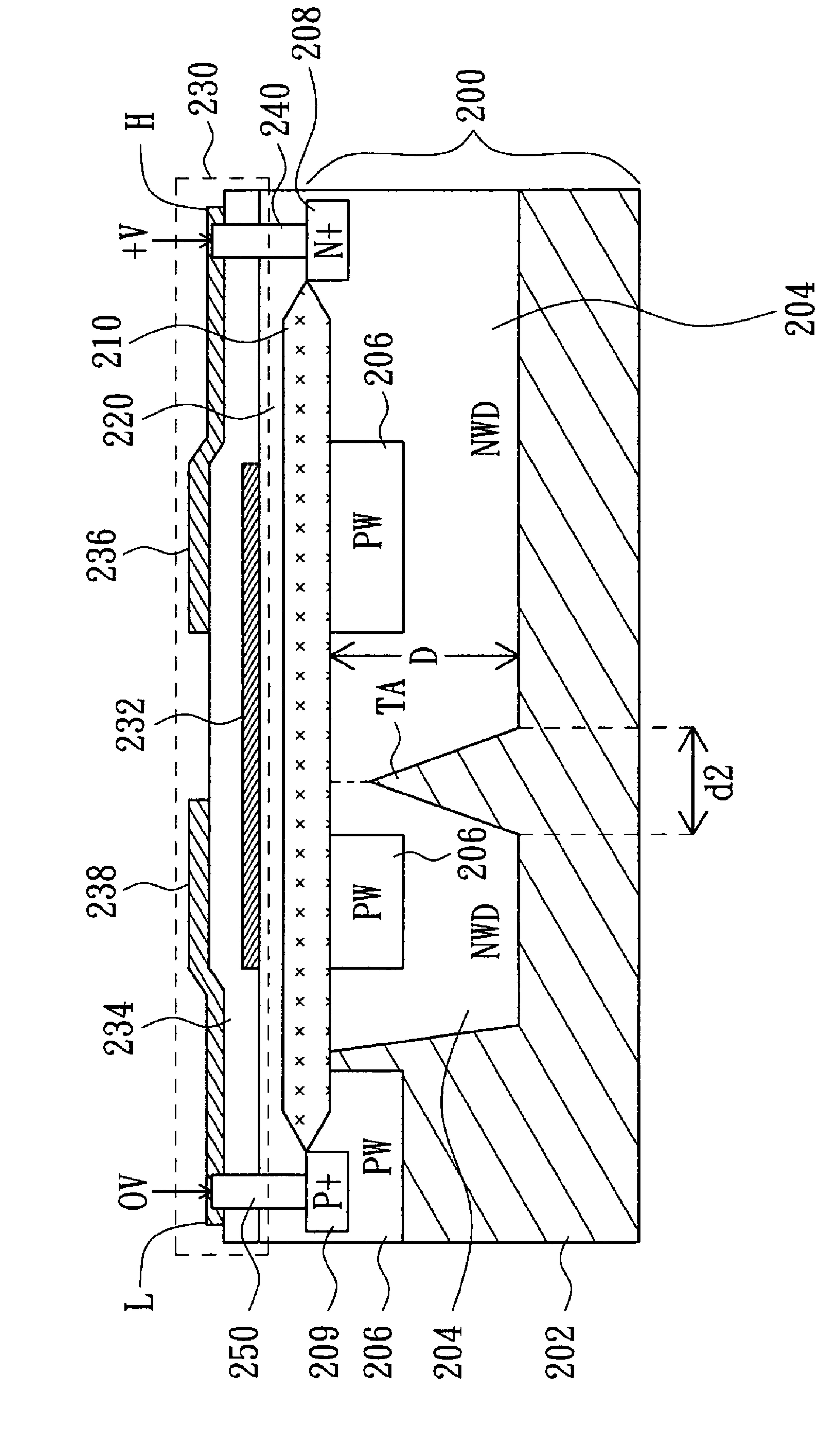

200
208
240
230
H
+V
N+
210
220
206
204
NWD
PW
236
232
238
234
D
TA
d2
OV
P+
L
250
209
206
204
202

FIG. 2

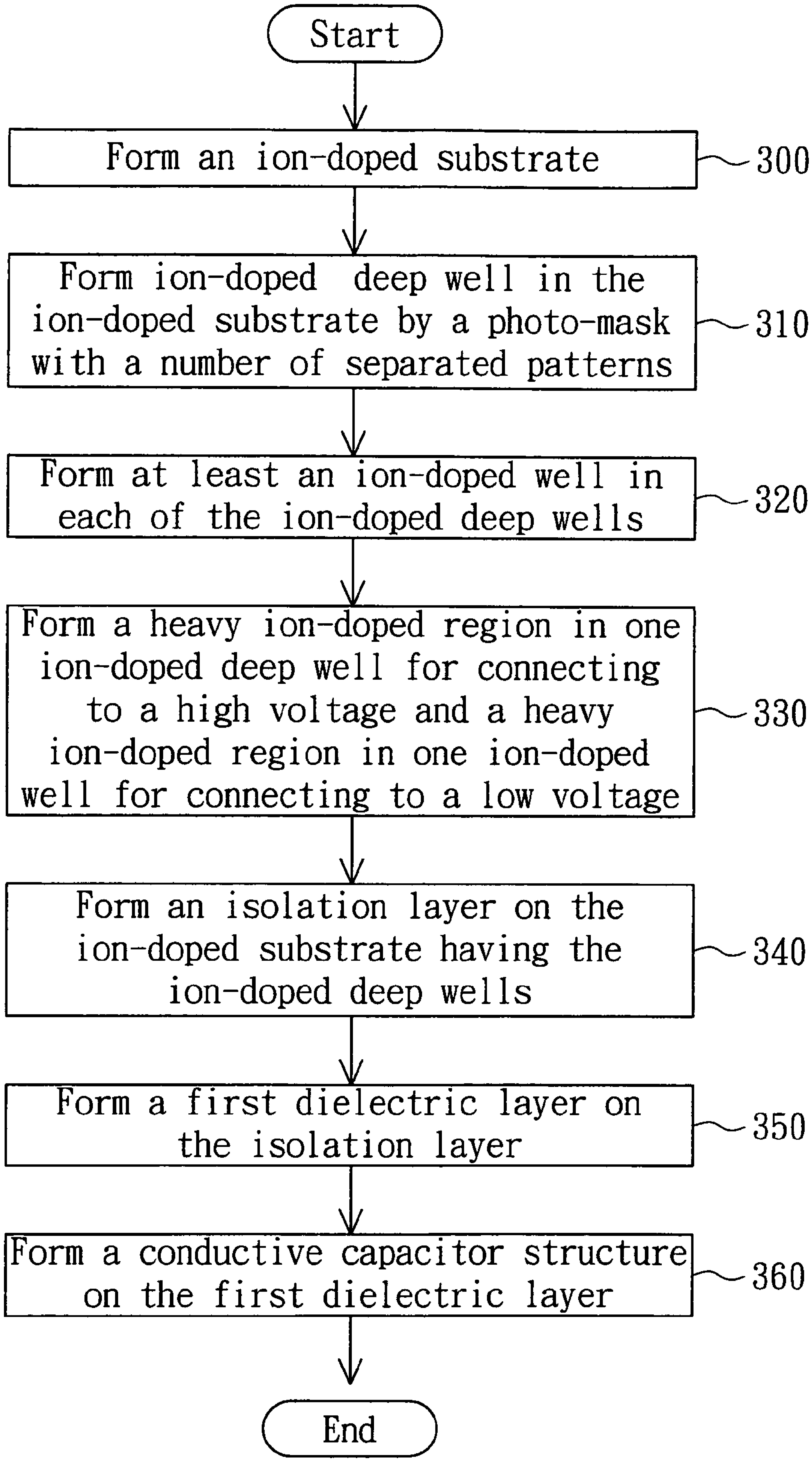

Start
Form an ion-doped substrate
300
Form ion-doped deep well in the ion-doped substrate by a photo-mask with a number of separated patterns
310
Form at least an ion-doped well in each of the ion-doped deep wells
320
Form a heavy ion-doped region in one ion-doped deep well for connecting to a high voltage and a heavy ion-doped region in one ion-doped well for connecting to a low voltage
330
Form an isolation layer on the ion-doped substrate having the ion-doped deep wells
340
Form a first dielectric layer on the isolation layer
350
Form a conductive capacitor structure on the first dielectric layer
360
End

FIG. 3

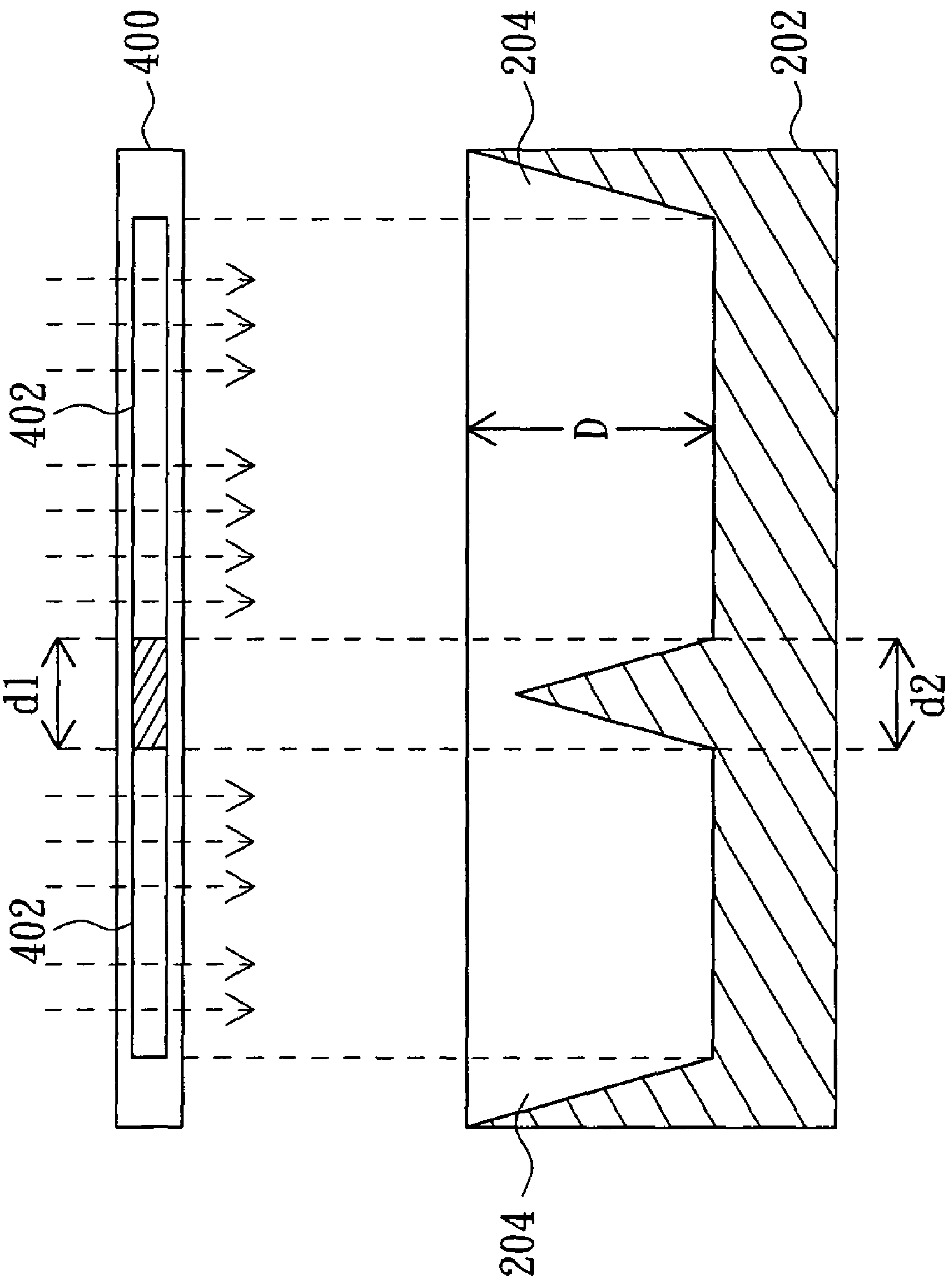


FIG. 4

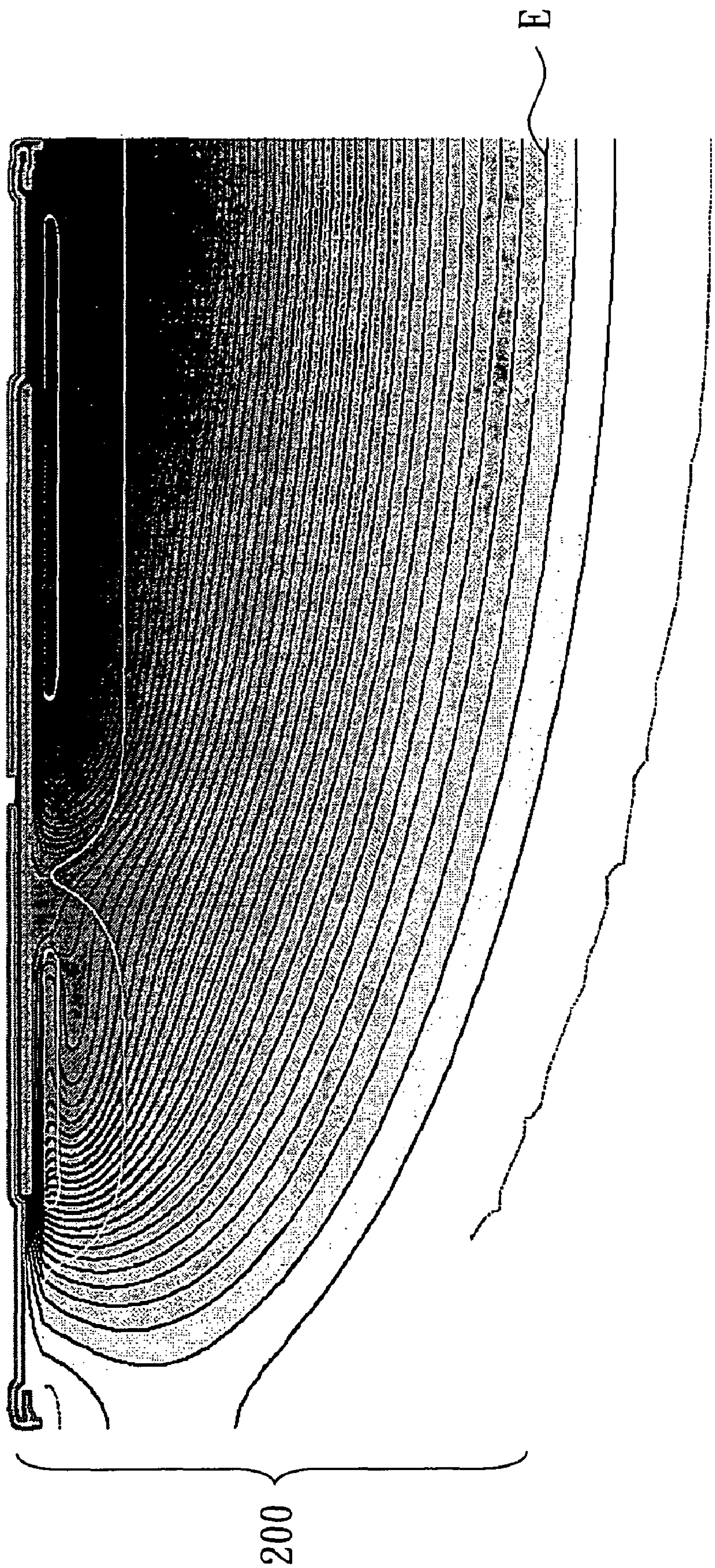


FIG. 5

SEMICONDUCTOR STRUCTURE OF A HIGH SIDE DRIVER AND METHOD FOR MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to a semiconductor structure, and more particularly to a semiconductor structure of a high side driver and method for manufacturing the same.

2. Description of the Related Art

FIG. **1** is a partial cross-sectional diagram of a semiconductor structure of a high side driver in a conventional power supply IC. Referring to FIG. **1**, the semiconductor structure of a high side driver includes a high voltage (HV) junction **110** formed in a P-substrate **100** and a high voltage (HV) capacitor structure **120** formed on the P-substrate **100**. The HV junction includes a deep N well (NWD) **112** and a number of P-wells (PW) **114**. The HV capacitor structure **120** includes a first metal layer **122** and two separated second metal layers **124** and **126**. The second metal layer **124** is connected to a low voltage, such as 0V, and the second metal layer **126** is connected to a high voltage +V, such as 500V. A heavy ion-doped N+ well **116** is formed between the P wells **114** for connecting to the second metal layer **126** via a bonding metal **130**.

Basically, an over-large conductive material covered on the HV junction **110** will reduce the breakdown voltage of the HV junction **110**. In order to prevent the breakdown voltage of the HV junction **110** being reduced by conductors (metals) in the HV capacitor structure **120**, conventionally, the HV capacitor structure **120** is disposed in a region of the P-substrate **100** separated from that region forming the HV junction **110** as shown in FIG. **1**, and is connected to the HV junction **110** via the bonding metal **130**. However, the conventional semiconductor structure of a high side driver has the following disadvantages:

1. It needs more chip space to dispose the HV junction **110** and HV capacitor structure **120** in separated regions of the P-substrate **100**.

2. It needs an extra bonding metal **130** for connecting the HV junction **110** and HV capacitor structure **120**, and thus more cost for manufacturing the power supply IC.

3. The dielectric layer between the first metal layer **122** and the second metal layers **124** and **126** needs to have a thickness of at least 1.5 um so that the capacitor structure **120** can endure the high voltage 500V. However, too large thickness of the dielectric layer will result some issues, such as yield reduction of the power supply IC.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a semiconductor structure of a high side driver, which integrates a HV junction with a HV capacitor structure, and method for manufacturing the same. The breakdown voltage of the HV junction can be increased by forming a number of partially separated deep N wells in the HV junction. Therefore, the HV capacitor structure can be integrated with the HV junction without affecting the breakdown voltage of the HV junction, thereby reducing the chip area and cost for manufacturing the power supply IC.

The invention achieves the above-identified object by providing a semiconductor structure of a high side driver including an ion-doped junction and an isolation layer. The ion-doped junction has a number of ion-doped deep wells, and the ion-doped deep wells are separated but partially linked with each other. The isolation layer is formed on the ion-doped junction.

The invention achieves the above-identified object by providing a method for manufacturing a semiconductor structure of a high side driver. The method includes forming an ion-doped substrate; forming a number of ion-doped deep wells in the substrate, wherein the ion-doped deep wells have a complementary ion-doped type to the ion-doped substrate and the ion-doped deep wells are separated but partially linked with each other; and forming an isolation layer on the ion-doped substrate having the ion-doped deep wells.

Other objects, features, and advantages of the invention will become apparent from the following detailed description of the preferred but non-limiting embodiments. The following description is made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial cross-sectional diagram of a semiconductor structure of a high side driver in a conventional power supply IC.

FIG. **2** is a partial cross-sectional diagram of a semiconductor of a high side driver in a power supply IC according to a preferred embodiment of the invention.

FIG. **3** is a flow chart of a method for manufacturing the semiconductor structure of a high side driver in FIG. **2**.

FIG. **4** is a schematic diagram of an ion doping process for forming the partially linked ion-doped deep wells in FIG. **2** by using a photo-mask with separated patterns.

FIG. **5** is a simulation potential profile of the semiconductor structure of a high side driver according to the preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **2**, a partial cross-sectional diagram of a semiconductor of a high side driver in a power supply IC according to a preferred embodiment of the invention is shown. The semiconductor structure of a high side driver includes an ion-doped junction (HV junction) **200**, an isolation layer **210**, a first dielectric layer **220** and a conductive capacitor structure **230**. The isolation layer **210**, such as an oxide layer, is formed on the ion-doped junction **200**, the first dielectric layer **220** is formed on the isolation layer **210**, and the conductive capacitor structure **230** is formed on the first dielectric layer **220**.

The ion-doped junction **200** includes an ion-doped substrate **202** and a number of ion-doped deep wells **204** formed in the substrate **202**, which are separated but partially linked with each other at an area near the isolation layer **210**. For example, the ion-doped junction **200** is p-n junction, the ion-doped substrate **202** is a P-substrate and the ion-doped deep wells **204** are deep N wells (NWD) formed in the P-substrate. It can be seen from FIG. **2** that the ion-doped deep wells **204** do not connect to each other completely and an approximately-triangular area TA of the substrate **202** is formed at the region between the ion-doped deep wells **204**. By forming the partially-linked ion-doped deep wells **204**, the breakdown voltage of the ion-doped junction **200** can be adjusted by tuning the distance d2 between the ion-doped deep wells **204**. The doping concentration of the ion-doped deep well **204** is preferably from 1.7E17 cm^{-3} to 8.3E18 cm^{-3}, and the depth D of the ion-doped deep well **204** is preferably from 2 um to 10 um.

Besides, the ion-doped junction **200** further includes at least an ion-doped well **206**, such as a P-well or P-body, in each of the ion-doped deep wells **204**. These ion-doped wells **206** are used to increase the breakdown voltage of the ion-doped junction **200**, and the breakdown voltage of the ion-doped junction **200** is determined by the shape and relative position of the ion-doped well **206** in the ion-doped deep well **204**. The doping concentration of the ion-doped well **106** is preferably from 3.3E17 cm^{-3} to 1E19 cm^{-3}. The ion-doped junction **200** further includes a heavy ion-doped region **208**, such as an N+ region, connected to a highest potential node H of the conductive capacitor structure **230** through a via **240** and a heavy ion-doped region **209**, such as a P+ region, connected to a lowest potential node L of the conductive capacitor structure **230** through a via **250**. The depth D of the ion-doped deep wells **204** should be adjustable in a direct proportion according to a high voltage +V (500V~700V) applied to the conductive capacitor structure **230** so as to maintain an enough breakdown voltage of the ion-doped junction **200**.

Furthermore, the conductive capacitor structure **230** includes a first metal layer **232**, a second dielectric layer **234** and two second metal layers **236** and **238**. The first metal layer **232** is formed on the first dielectric layer **220**. The second dielectric layer **234** is formed on the first metal layer **232**. The second metal layers **236** and **238** are separated and formed on the second dielectric layer **234**. The second metal layer **236** and the first metal layer **232** form a first capacitor. The second metal layer **238** and the first metal layer **232** form a second capacitor, which is connected to the first capacitor in series. The second metal layer **236** is connected to the high voltage +V and the second metal layer **238** is connected to a low voltage, such as 0V. The breakdown voltage of the ion-doped junction **200** is also determined by the position of the first metal layer **232** relative to the ion-doped junction **200** or the thickness of the first dielectric layer **220**.

FIG. **3** is a flow chart of a method for manufacturing the semiconductor structure of a high side driver in FIG. **2**. Referring to FIG. **2** and FIG. **3** simultaneously, first, in step **300**, form the ion-doped substrate **202**, such as a P-substrate. Next, in step **310**, form the ion-doped deep wells **204**, such as deep N wells, in the ion-doped substrate **202** by a photo-mask **400** with a number of separated patterns **402** as shown in FIG. **4** in a thermal drive-in process during a temperature from 1000° C. to 1200° C. for 6~12 hours. Owing that the patterns **402** of the photo-mask **400** are separated by a predetermined distance d**1**, the ion-doped deep wells **204** formed in the ion doping process are separated but partially linked with each other at an area near the upper surface of the ion-doped substrate **202**. The distance d**1** of the separated patterns **402** is proportional to the distance d**2** between the ion-doped deep wells **204**. The doping concentration of the ion-doped deep well **204** is preferably from 1.7E17 cm^{-3} to 8.3E18 cm^{-3}, and the depth D of the ion-doped deep well **204** is preferably from 2 um to 10 um.

The main feature of the embodiment lies in the partially separated ion-doped deep wells **204** help to increase the breakdown voltage of the ion-doped substrate **202** and ion-doped deep wells **204** and thus the capacitor structure formed on the ion-doped substrate **202** in the subsequent process will not affect or worsen the breakdown voltage of the ion-doped substrate **202** and ion-doped deep wells **204**.

Following that, in step **320**, form at least an ion-doped well **206**, such as a P-well or a P-body, in each of the ion-doped deep wells **204** in a thermal drive-in process during a temperature 900° C. to 1100° C. for 2~6 hours. The ion-doped wells **206** help to increase the breakdown voltage of the ion-doped substrate **202** and ion-doped deep wells **204**, and the doping concentration of the ion-doped well **206** is preferably from 3.3E17 cm^{-3} to 1E19 cm^{-3}.

Afterward, in step **330**, form the heavy ion-doped region **208**, such as a N+ region, in one ion-doped deep well **204** for connecting to the high voltage +V and the highest potential node H of the conductive capacitor structure **230**, and the heavy ion-doped region **209**, such as a P+ region, in one ion-doped well **206** for connecting to the low voltage 0V and the lowest potential node L of the conductive capacitor structure **230**.

Then, in step **340**, form the isolation layer **210**, such as an oxide layer, on the ion-doped substrate **202** having the ion-doped deep wells **204** (i.e. the ion-doped junction **200**), and in step **350**, form the first dielectric layer **220** on the isolation layer **210**. Finally, in step **360**, form the first metal layer **232** on the first dielectric layer **220**, the second dielectric layer **234** on the first metal layer **232** and the two separated second metal layers **236** and **238** on the second dielectric layer **234** to generate the conductive capacitor structure **230**. The highest potential node H and the lowest potential node L of the conductive capacitor structure **230** are respectively connected to the heavy ion-doped region **208** and **209** through contacts **240** and **250**.

As mentioned above, the breakdown voltage of the conductive capacitor structure **230** is also affected by the ion-doped junction **200**. Due to design of the partially separated ion-doped deep wells **204**, the conductive capacitor structure **230** placed on the ion-doped junction **200** can endure the high voltage 500V by using the second dielectric layer **234** with a thickness only 0.75 um.

Referring to FIG. **5**, a simulation potential profile of the semiconductor structure of a high side driver according to the preferred embodiment of the invention is shown. From FIG. **5**, it can be clearly seen that the electric field E inside the ion-doped junction **200** is very uniform, which demonstrates that a good performance of the high side driver can still be achieved by using the ion-doped junction **200** with the partially separated ion-doped deep wells (not shown in the figure).

The semiconductor structure of a high side driver and method for manufacturing the same disclosed by the above-mentioned embodiment have the following advantages:

1. The chip area for disposing the semiconductor structure of a high side driver can be reduced by integrating the conductive capacitor structure with the HV junction.

2. The prior-art bonding metal for connecting the capacitor structure and HV junction is not necessary in the invention since the capacitor structure can be integrated with the HV junction, thereby largely reducing cost for manufacturing the power supply IC.

3. The breakdown voltage of the HV junction will not be affected by the integrated capacitor structure and a good performance of the power supply IC can be achieved.

4. The dielectric layer between the split metals of the capacitor structure only needs to have a thickness 0.75 um in order that the capacitor structure can endure a 500V high voltage.

While the invention has been described by way of example and in terms of a preferred embodiment, it is to be understood that the invention is not limited thereto. On the contrary, it is intended to cover various modifications and similar arrangements and procedures, and the scope of the appended claims therefore should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements and procedures.

What is claimed is:

1. A semiconductor structure of a high side driver, comprising:

an ion-doped junction, having an ion-doped substrate and a plurality of ion-doped deep wells formed in the ion-doped substrate, wherein the ion-doped deep wells are separated but have partial and physical connection with each other at a region within the ion-dope substrate; and

an isolation layer, formed on the ion-doped junction.

2. The semiconductor structure according to claim **1**, further comprising a conductive capacitor structure formed on the isolation layer.

3. The semiconductor structure according to claim **2**, wherein the ion-doped substrate is a P-substrate and the ion-doped deep wells are N-wells formed in the P-substrate.

4. The semiconductor structure according to claim **2**, wherein the breakdown voltage of the ion-doped junction is determined by the distance between the ion-doped deep wells.

5. The semiconductor structure according to claim **2**, wherein the ion-doped junction further comprises at least an ion-doped well in each of the ion-doped deep wells and the ion-doped well has a complementary ion-doped type to the ion-doped deep well.

6. The semiconductor structure according to claim **5**, wherein the breakdown voltage of the ion-doped junction is determined by the shape and relative position of the ion-doped well in the ion-doped deep well.

7. The semiconductor structure according to claim **5**, wherein the doping concentration of the ion-doped well is from 3.3E17 cm-3 to 1E19 cm-3.

8. The semiconductor structure according to claim **2**, wherein the ion-doped junction further comprises a heavy ion-doped region having the same ion-doped type with the ion-doped deep wells, and the heavy ion-doped region is connected to a highest potential node of the conductive capacitor structure.

9. The semiconductor structure according to claim **2**, wherein the depth of the ion-doped deep wells is directly proportional to a high voltage applied to the conductive capacitor structure.

10. The semiconductor structure according to claim **9**, wherein the depth of the ion-doped deep well is from 2 um to 10 um.

11. The semiconductor structure according to claim **2**, wherein the isolation layer is an oxide layer.

12. The semiconductor structure according to claim **2**, further comprising a first dielectric layer formed between the conductive capacitor structure and the isolation layer.

13. The semiconductor structure according to claim **12**, wherein the conductive capacitor structure comprising:

a first metal layer, formed on the first dielectric layer;

a second dielectric layer, formed on the first metal layer; and

a plurality of separated second metal layers, formed on the second dielectric layer, wherein one of the second metal layers is connected to a high voltage and another one of the second metal layers is connected to a low voltage.

14. The semiconductor structure according to claim **13**, wherein the breakdown voltage of the ion-doped junction is determined by the position of the first metal layer relative to the ion-doped junction.

15. The semiconductor structure according to claim **2**, wherein the doping concentration of the ion-doped deep well is from 1.7E17 cm-3 to 8.3E18 cm-3.

16. The semiconductor structure according to claim **2**, wherein the ion-doped deep wells are partially linked to each other at an area near the isolation layer.

17. The semiconductor structure according to claim **2**, is applied to a power supply IC.

* * * * *